A National Program of Research for

SOIL AND LAND USE

Prepared by

A JOINT TASK FORCE OF THE
U. S. DEPARTMENT OF AGRICULTURE
AND THE STATE UNIVERSITIES
AND LAND GRANT COLLEGES

FOREWORD

The United States Department of Agriculture and State Agricultural Experiment Stations are continuing comprehensive planning of research. This report is a part of this joint research planning and was prepared under recommendation 2 (page 204, paragraph 3) of the National Program of Research for Agriculture.

The task force which developed the report was requested to express their collective judgment as individual scientists and research administrators in regard to the research questions that need to be answered, the evaluation of present research efforts, and changes in research programs to meet present and future needs. The task force was asked to use the National Program of Research for Agriculture as a basis for their recommendation. However, in recognition of changing research needs it was anticipated that the task force recommendations might deviate from the specific plans of the National Program. These deviations are identified in the report along with appropriate reasons for change.

The report represents a valuable contribution to research plans for agriculture. It will be utilized by the Department and the State Agricultural Experiment Stations in developing their research programs. It should not be regarded as a request for the appropriation of funds or as a proposed rate at which funds will be requested to implement the research program.

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This report has been prepared in limited numbers. Persons having a special interest in the development of public research and related programs may request copies from the Research Program Development and Evaluation Staff, Room 318-E Administration Bldg., USDA, Washington, D.C. 20250.

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PREFACE

In response to a request from the Senate Committee on Appropriations, the U.S. Department of Agriculture and the Association of State Universities and Land-Grant Colleges conducted a study on all agricultural research. This led to the October 1966 report entitled "A National Program of Research for Agriculture."

The recommendations made in the report urged the appointment of *ad hoc* interdisciplinary committees of scientists to provide in-depth reviews of designated research subject-matter areas. Accordingly, a committee was designated by the U.S. Department of Agriculture and the Land-Grant Colleges. This committee has concerned itself with this assignment. The results of the deliberations are contained in the following report. Members of the task force were the following people:

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INTRODUCTION

Use of the land involves both private and public interests. Today it is widely acknowledged that the public purpose is not being achieved satisfactorily. This failure results in part from inadequate knowledge of physical techniques and also from faulty social organization for promoting legitimate private interests. Before a desirable public land policy can be developed, an understanding of the broad human problems with which the social scientist deals must be related to the technical findings of the soil scientists.

Land belongs to a boundless family--some dead, a few living, and an untold number yet to be born. The unborn must be assured that there will be adequate soil resources for food production, for urban development, and for the many intangibles that make life richer.

As our society grew, the wants of our people were satisfied because our labor became skilled; tools were accumulated; and land was utilized more fully. However, the land area has remained the same and will remain the same in the future. In 1960, the world ratio was 1.2 acres per person. By 1970, this will have dwindled to 0.9 acre per person. It is estimated that by the year 2000, there will be less than 0.5 acre per person.

In the last two decades, population growth and migration from rural areas and small towns have brought increased pressures on land around our major cities. Although a small percentage of the total land surface is involved in urban developments, land prices have caused irreversible shifts from rural use.

Larger populations with increased incomes and shorter work weeks have increased the pressure for space for outdoor recreation. The number of people visiting our national parks has increased manyfold over the last two decades, and experts estimate that by 1980, national parks, wilderness areas, and game refuges will have four times as many visitors as they had in 1968.

If we are to maintain an abundance of food and fiber at reasonable prices, the first requirement of our lands will be to increase its capacity to produce. Thinking in terms of maximum needs is not an innovation, although the demands for food and the desire of the farmer to be more efficient through more production per acre has focused increased attention on high yields. Because our thinking regarding maximum yields has changed, the researcher or farmer is no longer satisfied with growing record yields. Experience in the past and a prognosis for the future convince both of them that larger yields can be produced with proper crop varieties and environmental conditions.

The presence of hunger and malnutrition, affecting millions of human beings in the world, cannot be ignored even if we live in one of the most affluent nations. When food production remains the same or fails to keep pace with the population growth, food shortages, hunger and starvation become realities. Intelligent solutions to this bitter problem must be found. The research proposed by this committee should provide the information needed to produce adequate food and fiber for a growing world population.

The underfed nations must be helped to produce for themselves on their own underdeveloped or poorly used land. The sharing of 20th-century technology can be our contribution. Therefore, the research needs projected in this report should provide training opportunities for scientists and producers in the developing countries.

Increased labor and equipments costs have resulted in the farmer and rancher controlling weeds by herbicides rather than tillage. Larger amounts of fungicides, pesticides, and chemical fertilizers are being used today.

As our population has grown, problems of air, water, and soil pollution have caused great public concern. The magnitude of organic waste production in the United States and the rate of annual increase in tonnage are creating a massive disposal problem. With increasing public demand and legislative requirements for cleaning up the environment, it is becoming obvious that the present methods of disposal are neither adequate nor acceptable. As as result, there is increasing attention being turned to disposal on agricultural lands.

Theoretically, the only limit to how much waste can be disposed of per acre of land is how high one wishes to pile it. However, disposal on land implies eventual microbial degradation with loss of carbon as CO_2 and the accumulation of secondary "wastes" including inorganic ions. The accumulation of inorganic ions and degradation products can result in air and water pollution.

Recent increases in the number of meat and milk animals and changes in livestock handling methods have resulted in concentrations of large numbers of animals on small units of land. This has resulted in the accumulation of large tonnages of animal wastes that contain enormous quantities of nitrogen and phosphorus. Manure disposal is becoming a major problem that may add substantially to consumer costs. This trend will continue unless waste disposal by regulations and economics force moving animal and poultry operations to sites with lesser pollution hazards.

The Task Force Assignment

The Soil and Land Use Task Force has been charged with the evaluation of research needs in soils related to agriculture. In developing these needs, the committee has assumed that our soil resources should be used to maintain a sustained high standard of living for the people in the United States

as well as those in developing countries. However, in assuming this responsibility, the committee has also been concerned with urban, recreational, and other land uses that will meet the needs of the people without polluting our soil and water resources.

Problems needing additional effort and areas where less support should be considered were examined. The adequacy and balance of the scientific effort as a whole, both from a short- and long-range viewpoint, were evaluated.

The manpower projections are the best estimates of the Task Force. It is recognized that manpower shortages in certain disciplines will create staffing problems. However, in all phases of the work, the training aspect is considered to be an important part of the proposal.

Organization of the Report

The report is divided into five major areas. Within each area, several specific proposals have been developed. Major areas included are as follows:

APPRAISAL OF SOIL RESOURCES
SOIL STRUCTURE; and SOIL, WATER, PLANT, NUTRIENT RELATIONSHIPS
MANAGEMENT OF SALINE AND SODIC SOILS
ALTERNATIVE USES OF LAND
POLLUTION

The specific proposal under each of the subheadings above outlines the present situation, the objectives of the research, the research approaches planned, the character of the potential benefits and projected scientific man-years (SMY's). Tables at the end of the report give the total manpower projected in each major area and compare these with those working on the problems in 1968.

APPRAISAL OF SOIL RESOURCES

The soil is one of the Nation's basic natural resources. Its character and its capabilities vary widely from place to place, commonly within distances of a few hundred feet. To use the soil resource wisely and economically, we must know what it is like and how it will perform wherever we want to adapt it to our needs. This is the ultimate purpose of research in this problem area.

Responsibility for leadership of a national inventory of soil resources has been vested by Congress in the United States Department of Agriculture. That agency has developed a system for classifying soils and for making and publishing maps that show where the different kinds of soil occur. The mapping is done in cooperation with the States under a program known as the National Cooperative Soil Survey.

Initially soil maps and reports were used mainly for farming, ranching, and forestry, and the information was assembled with those uses in mind. In our rapidly urbanizing and expanding industrial economy, however, those who invest large amounts of capital in physical facilities in or on the soil have also found soil maps extremely valuable. Soil maps are now used widely to predict suitability of soil at a given place to support schools and houses, to absorb septic tank effluent, to support roads, to carry pipelines or conduit, to develop lawns and playgrounds, and to permit lasting installations of many other kinds. In some areas, building permits are issued only after soil maps have shown that soil conditions are suitable. The demand for soil maps and for basic information about soil character has increased dramatically.

The mapping of soils is not considered research in the Federal budgeting process and is not properly included in this report of research needs. The new uses of soil maps, however, have raised new problems which require research. We need to find ways to make maps more rapidly and more accurately to meet new demands. We must provide new and better information about soil character so the maps can be applied to new as well as old uses. We must develop systems by which the information about soil character can be assembled quickly and cheaply in different forms adapted to a great variety of uses. The research needs described for this problem area are for these purposes. They are needed to adapt the existing program of soil surveys to the increasing demands of the predominantly urban and industry-oriented population for information in support of enterprises having very large capital investments in soil-related physical facilities. These needs are listed under four major projects.

A. Inventory of Fundamental Properties and Processes of Soils
B. Development and Use of Soil Maps and Data
C. Soil Classification and Correlation
D. Soil Factors Influencing Animal and Human Nutrition

It should be noted that projects A, B, and C are so intimately related to the soil mapping of the National Cooperative Soil Survey that they cannot logically be divorced from that program. This creates an administrative dilemma, as the Federal agency charged with the leadership of national soil inventory is not a research agency, though it has substantial research competence. For effective prosecution of the research required, approximately 50 percent of the research effort and the leadership for these three projects should be vested in that agency or in another very closely coordinated Federal agency. The remainder should be distributed among a limited number of qualified cooperating State agencies so located as to permit development of regional subprojects for those elements of the projects having geographic distribution of soils as major factors.

Leadership of project D would appropriately be centered in the U.S. Plant, Soil, and Nutrition Laboratory. Approximately 50 percent of the effort should be done by the State experiment stations having competencies in the area and strategically located with respect to the problems.

Inventory of Fundamental Properties and Processes of Soils

Situation: The properties of soil and the processes that go on in it determine how well or how poorly it will serve different uses, and more importantly in the modern economy, what must be done and how much it will cost to change the soil to serve man's needs. Eighty thousand kinds of soil differing in properties and processes significant for use exist in the United States alone. The areas of these different kinds are being delineated on soil maps nationwide; modern soil maps are available for 1,200,000 square miles in the United States. The maps permit us to predict how the soil will perform and what management is needed at any given place for efficient use without destroying the resource.

We have accumulated much good information about soil properties which can be determined in the field. As the demands on the soil increase in our modern society, however, the increasing intensity of soil use and the large capital inputs required demand information which only laboratories and more sophisticated field studies can provide. Currently, these needs are served by three understaffed National Soil Survey Laboratories, three special State laboratories and supplementary piecemeal local efforts, principally in 12 States. A major coordinated effort planned deliberately to develop a body of data pertinent to modern problems is essential for orderly and efficient use of soil resources.

Objective: To assemble a body of quantitative knowledge about soil properties and soil processes for predicting the behavior of soils and their requirements for use in modern society.

Research Approaches:

A. Develop a bank of characterization data for the major kinds of soil pertinent to modern problems. This involves development of some new methods and improvement of some old ones for efficiency, as well as application of standard physical and chemical laboratory characterization methods.

B. Characterize quantitatively the additions, losses, and retention of selected chemical constituents in major kinds of soil. These should include plant nutrients, certain components of pollutants, and elements critical in soil formation. The data would be used to define how different soils will perform under various uses.

C. Characterize the temperature and moisture of major soils with time in relation to weather and site conditions. This information is needed to predict changes in soils with changing seasons and what effect these changes have on both biological and engineering problems.

D. Characterize the physical properties of subsoils and substrata. This would require development of measurements meaningful for application to both engineering problems and problems of root and other biological activity.

E. Determine the relationship of present soil character to geomorphic and climatic history. We must know these relationships to explain present conditions and predict future soil changes in a cultural environment.

F. Develop methods and determine the character and reactions of the non-crystalline fraction of soil and its interactions with the crystalline fraction. Although more than half of the clay fraction of some soils is noncrystalline, we know little about it and its influence on use of soil.

G. Develop principles of the ecology of soil micro-organisms in relation to soil character and environment. The possibility of controlling the character of soil micro-organism populations has been demonstrated in a few instances but has not been explored in terms of potential for waste disposal, disease control, and pollution abatement.

H. Develop methods for determining the degree of profile modification resulting from ecological succession--from conversion of forest type or from forest to grass.

Character of Potential Benefits: As the research proposed is in support of applied objectives which involve other inputs, it is not possible to estimate dollar benefits from such work by itself. What, for example, is the potential value of the data to be assembled under Research Approach A when applied to location of a highway for which the cost of failure of one mile on unsuitable soil is measured in millions of dollars? Or, what is the value of such data applied to foundations of thousands of $20,000 homes or to corrosion problems of hundreds of miles of pipeline? What is the value of Research Approach B applied to water pollution from millions of acres of land, or of Research Approach C applied to soil as a medium for disposal of wastes? These examples are nonagricultural, but they are typical of the uses of soil maps and data, which are prepared by agricultural institutions. The data are equally applicable to biology and agriculture, also in combinations with other kinds of inputs.

Projected SMY's:

1965	1977
25	50

Development and Use of Soil Surveys

Situation: The USDA with modest cooperative input from State and other Federal agencies is currently making soil maps at the rate of a little over 50 million acres a year, and about 750 million acres have been mapped with sufficient detail and accuracy to meet most present-day needs. About one billion acres remain needing detailed soil maps. The USDA program of making and publishing soil surveys, costing about 21 million dollars a year, is not included with research in the inventory of the National Program of Research for Agriculture.

As the intensity of soil use and the capital inputs for that use increase, demands multiply for the information soil surveys provide. It is necessary to develop techniques for greater efficiency of both soil mapping and the interpretation of soil survey information to meet those demands and to maximize returns for funds expended on soil surveys.

In range country and areas of extensive farming, power equipment as an aid to mapping is now used widely, but field mapping methods in the humid parts of the country have changed little in the past 30 years. The basic problem is that the soil scientist cannot drive a vehicle over a field where a crop is growing, over rough mountainous forested land, or across field or property boundaries marked by physical barriers. Cartographic techniques in compiling and printing the maps have been greatly simplified.

Interpretations of soil maps are statements or predictions based on research and experience of the nature and severity of problems or limitations of the kinds of soil for various alternative uses. They are being made for a wide spectrum of uses, such as farming, forest management, public land management, residential, highway construction and other engineering uses, waste disposal, and recreation. The demands increase yearly. These interpretations are published or made specially for counties or townships, using local experience in addition to limited physical and chemical data. A very considerable body of experience is not tapped because as yet information retrieval systems on soil behavior have not been developed.

Objectives: To develop techniques for increased efficiency of soil mapping and interpretations, both in terms of quantity and quality, and broadening the applicability of the maps and interpretations in land use planning.

Research Approaches:

A. Techniques that need to be studied to increase the rate of mapping and the quality of soil maps include:

  1. Application of devices used for remote sensing. Remote sensing with infrared sensitive film at the proper season indicates areas

with differences in soil moisture more precisely than other film. These differences can be extremely important to interpretations.

2. Special instrumentation for field investigations of soil properties. It should be possible to devise instruments to measure in the field important soil properties that now require laboratory studies. Field techniques could give semiquantitative data that are as valid as quantitative laboratory data insofar as any possible interpretations are concerned. Because more such data could be obtained in the field, the quality of interpretations could be greatly enhanced.

3. New aspects of aerial photography. To what extent can high altitude photography substitute for mosaics?

B. Techniques for information storage and retrieval:

1. Cartographic possibilities for use of computers in map compilation and geographic information retrieval.

2. Development of systems for information storage and retrieval on soil behavior important to interpretations.

C. Quantitative evaluation of soil variability within mapping units and its relation to their nomenclature and to interpretations. There are small or large variations in soil properties within each delineated area on a soil map. If variability is known to be large, it is reflected by the soil name. Too little is known, however, about variability in delineations thought to be reasonably homogeneous. Studies are needed to determine the nature of this variability and the relation of the variability to the intended uses of the maps.

Character of Potential Benefits: Studies of cost-benefit ratios of soil surveys show the ratios range widely according to inputs or investments. In farming areas the cost-benefit ratios over the 25-year life expectancy of maximum usefulness of the soil surveys is about 1 to 60. In areas of rapidly expanding population and industry, the ratio is about 1 to 125. Increased efficiency in both rate and accuracy of mapping and in retrieval of information for interpretations should lead to cheaper and better maps and greater numbers and accuracy of interpretations. With increasing costs of farming and greater public awareness of the utility of soil interpretations for housing and highway and other construction, the cost-benefit ratios can at least be doubled within 10 years.

Projected SMY's:

1965	1977
25	35

Soil Classification and Correlation

Situation: Soils can be classified in as many ways as there are uses--for farming or forestry, for construction, for waste disposal, for recreation, or for underground power lines and pipe lines. Practical classifications, or groupings of soils, according to the kinds and severities of problems, are made to predict the consequences of alternative uses of the 80,000 specific kinds of soil currently recognized. These classifications, when combined with the soil maps, permit predictions for specific sites, and furnish land users with information needed to choose among alternative uses. Relevant information can thus be focused on a field or even on a point, and costly mistakes can be avoided.

Standing behind these classifications is a general classification that shows relationships between the kinds of soil in terms of their morphology, including their physical and chemical properties. This classification is new. It was adopted for use in 1965 after more than a decade of development. Many criteria of the system are new, and physical, chemical, and mineralogical data are inadequate for the classification of a number of soil series.

Some of the newer practical classifications needed for the expanding uses of soil surveys also are based on soil properties for which few data are available. New and more demanding uses of soil information have increased. While classifications are always subject to change with new knowledge, the needs to revise soil classifications or develop new ones are growing more rapidly than knowledge and ability to apply existing knowledge. The uses of soil as a sink for waste disposal, the problems of soil pollution and related water pollution, and the impact of modern intensification of production techniques on the soil resource itself are examples of problems that require new facts about different kinds of soils and the capacity to retrieve existing facts to be focused on the problems at specific places.

Objective: To develop data and techniques for increased accuracy and efficiency of interpreting soil survey information through improved classifications and correlations.

Research Approaches:

A. Development of quantitative data on which to base the practical classifications through:

1. Quality ratings for specific uses, such as crop production, housing, waste disposal, and hydrology. The design of the most economical and satisfactory foundations for houses is a function of the nature of the soil. Foundations can be far more expensive than necessary, or they can fail if improperly designed. Present

quality ratings indicate the nature of most problems satisfactorily, but give only a little information of the severity of problems that exist.

2. Production functions relating output to input. Yields of crops, forage, and wood products are influenced not only by the nature of the soil but also by management inputs. Far too few data are available to permit calculations that relate output to input as functions of the kinds of soil.

3. Physical inputs and their significance as capital inputs to remake or modify the soil for desired uses. Unfavorable soil properties can be modified in many places to adapt the soil for desired uses. This may require shaping or levelling one soil, removing a hardpan from another, and so on. Data on costs versus the effects of modifying the soil are too few in most places to permit satisfactory analyses of alternative uses of capital.

B. Development of techniques for storage and retrieval of information to be used for:

1. Testing and improvement of criteria used for soil correlations. Present criteria for soil correlation and their limits have been selected to produce groups of reasonably homogeneous soils. The limits of the criteria need to be tested by regression analyses and need to be tested against alternatives. Before this can be done, methods for storage and retrieval must be developed to permit use of existing data by any institution. Coding to permit use of the data with any machine language on a wide variety of machines must be developed.

2. Study and improvement of criteria need for practical classifications. Techniques for storage of data for soil interpretations are essential but have received virtually no attention except for crop yields in two States and forest products in the USDA. A wide variety of experience must be stored, but studies of methods for coding are urgent.

C. Determination of the compatability of diagnostic soil properties in soil classification with the natural occurrence of mappable soil bodies. Diagnostic properties used in soil classification must be related to mappable bodies of soil to permit interpretations of the maps. Quantitative studies of the present diagnostic properties, selected by group judgment, are needed to determine what relations exist in the field and whether adjustments in limits or selection of alternatives would produce more reliable interpretations.

<u>Character of Potential Benefits</u>: Potential benefits from soil classification and correlation cannot be separated from the benefits from the use of soil surveys and are discussed there. The nature of the benefits from classification and correlation is a sharpening of predictions of consequences of alternative uses of specific kinds of soil.

<u>Projected SMY's</u>:

1965	1977
90	100

Soil Factors Influencing Animal and Human Nutrition

Situation: Certain areas where feed or forage plants contain deficiencies or toxic excesses of certain elements for animals that eat these plants have been identified in the United States. Animal deficiencies of cobalt, selenium, and iodine, and excesses of molybdenum and selenium have been traced to deficiencies or excesses of these elements in specific kinds of soil. The identification of such areas with animal health problems is, however, far from complete. Many areas have not been characterized and many known mineral deficiencies and toxicities have not been correlated with specific soil conditions. There is also evidence that some humans in the United States may be suffering from deficiencies of chromium or zinc, and perhaps other elements, but the extent to which these deficiencies may be due to deficiencies of these elements in the soils of certain areas is not known.

Studies are needed to establish levels of essential or "health-related" mineral elements in the soils and in the food and feed crop plants of different parts of the United States. Soil management practices may affect nutritional quality of plants, and with rapidly changing cultural practices, their impact on the problem should be known. The goal of such studies is improved efficiency of animal production through reduction of losses due to mineral deficiency or toxicity diseases, and potential improvements in human health through the recognition and elimination of causes of mineral deficiencies in human diets.

Objectives:

A. To expand fundamental knowledge of the relationship between the characteristics of specific soils and the nutritional quality of the plants grown on them.

B. To locate and characterize soil areas where the nutritional quality of plants is adversely affected by deficiencies or excesses of soil-derived mineral elements.

C. To evaluate alternative procedures such as soil treatments, crop selection, feed supplementation, etc., for correction of soil-related problems in the nutrition of man and animals.

Research Approaches:

A. Important feed and food crops produced in areas where animal nutritional diseases of unknown cause are experienced will be sampled and analyzed for critical nutrient elements, or potentially toxic elements. The results of these analyses will be compared with the geographic incidence of nutritional problems and to any recognized toxic or required levels of these elements.

B. Geochemical, pedological, and biochemical processes affecting the accumulation or depletion of "health-related" elements in soils and the availability of these elements to plants will be investigated. The purposes will be to provide an improved basis for identifying soils where nutritional quality of plants may be inadequate and to provide a basis for evaluating soil treatments or management measures designed to correct these problems.

C. The chemical form and nutritional value of certain important elements contained in different feed- and food-plant species will be determined. The effects of complementary and competitive nutritional interactions among the elements contained in plants will also be studied. The purpose will be to develop precise criteria for predicting the nutritional quality of plants from information of their mineral composition. These studies would involve the feeding of plants grown under controlled conditions to experimental animals, as well as chemical studies.

<u>Character of Potential Benefits</u>: The potential benefits of this work cannot be accurately quantified, but the improvement in efficiency of animal production may be substantial. Elimination of losses due to selenium deficiency in cattle, sheep, hogs, and poultry would increase efficiency of production of animal protein by an estimated 1 or 2 percent on a national basis. The value of this work to human health is even harder to quantify.

<u>Projected SMY's</u>:

1965	1977
19	39

SOIL STRUCTURE; AND SOIL, WATER, PLANT, NUTRIENT RELATIONSHIPS

This problem area includes a variety of soil and water factors bearing on efficiency of plant growth and resource use. Compaction or other soil profile conditions may limit water and root penetration to depths within or not much beyond the plowed layer. Such conditions limit water storage capacity and may contribute to excessive runoff and erosion. Restricted depth of rooting limits water availability to plants and leads to greater drought susceptibility. Research is needed on procedures for altering and improving profile conditions to permit increased water movement and root penetration. Economic studies are needed to evaluate both the effects of profile limitations and the benefits resulting from treatment.

Tillage and residue management procedures influence soil structure, infiltration, runoff and erosion. There is evidence in some cases that tillage is excessive in relation to the requirement. Further studies are needed in the direction of minimum-tillage and plow-plant concepts of tillage operations. Organic residues should be managed so as to provide maximum contributions to soil structure and conservation with minimum interference to seedling establishment and contribution to disease conditions. There is need for information on the level of tillage required for different situations and for equipment which will accomplish essential tillage with a minimum input of energy.

High rates of fertilizer application are a major factor in present-day management and technology. New crop varieties are more responsive to high fertility. Increased rates of major nutrient application and intensity of crop production often lead to deficiencies of secondary and micronutrients. High nitrogen applications increase soil acidity and lime needs. Increased acidity limits root development and is difficult to correct in the subsoil. Microbial activities and resulting organic matter and nutrient transformations in the soil may be reduced and altered in course by fertilization practices and acidity conditions. Research is needed on interrelationships of fertilization practices, nutrient behavior, organic matter transformations, soil structure, air and water relations, and other factors which bear on efficient plant growth.

Increased fertilizer applications, particularly of nitrogen and phosphorus, have led to allegations concerning their pollution of water supplies. There is a critical need for research information on the behavior and fate of these elements in soils and the extent of movement from soils into water supplies.

With ever-increasing urbanization, there is an increased need for and use of soil characterization information in nonagricultural activities. Accurately interpreted information on physical conditions and moisture properties of

soils can be of great economic importance in connection with foundation stability, septic tank drainage, and a variety of other nonagricultural uses of soil.

Soil Profile Modification

Situation: Plant growth is largely dependent on effective use of precipitation and irrigation water. Many soils have profile conditions that limit water penetration, water storage, and the extent to which plant roots can proliferate the soil to extract water and nutrients. These undesirable soil conditions can be zones of high soil strength, coarse gravel, high content of toxic chemicals or deficiency of essential plant nutrients.

Undesirable profile chemical and physical conditions limit response to other management inputs on vast areas of the world. They are major factors in developing nations of the tropics and highly significant to agricultural efficiency in the United States. Restrictive soil profile conditions are especially serious in unique climatic zones where many of our essential fruit and vegetable crops must be produced. Examples are hardpan soils in Florida, acid subsoils along the East Coast, saline and sodic soils in the Southwest, and toxic zones in soils of the Pacific Northwest.

Physical conditions permitting increased water infiltration and movement in the soil would contribute substantially to runoff and erosion control and to effective field drainage. Physical and chemical conditions favoring deeper root penetration would increase water use efficiency and drought resistance of plants. Undesirable soil profile and topographic conditions may restrict use of the soil for nonagricultural uses such as housing developments, septic tank drain fields, and other engineering uses. In most cases, the undesirable soil condition can be alleviated by grading or by mixing one or several horizons of a soil profile and by adding amendments during mixing. Profile modification for agricultural purpose may range from plowing slightly deeper than normal to complete inversion of the profile to depths of several feet with or without the addition of varying amounts and kinds of amendments. One requirement for successful profile modification is complete description of the physical and chemical characteristics of the ideal profile for the intended use. This will permit determining the depth to which the profile must be disturbed and the amount and kind of additives necessary to convert undesirable profiles to desirable ones.

Objectives:

A. To determine the characteristics of an ideal profile for various uses.

B. To develop technology necessary to create soil profile conditions suitable for the intended use.

Research Approaches: Profile modification will usually involve development of chemical and physical conditions which permit control of air and water movement in the soil profile.

Determination of the characteristics of an ideal profile will include studies of the effects of particle size distributions and the chemical and physical makeup of the particles on the physical properties of the soil profile. For agricultural purpose, profile characteristics will be defined in terms of the effect of the profile on air and water movement in the soils on plant root growth, and also on the above-ground growth and on the desired product.

Studies will also evaluate the relative effectiveness of chemical and biological profile modification through use of special plants and combinations of chemical additive and mechanical mixing.

Studies will identify those profiles which should be modified and those on which modification is excessively costly or not feasible, and will provide information concerning the extent and kind of modification required. The economic soundness of practices and various combinations of practices will be evaluated.

Research will be required to design and develop machinery for effective profile modification at minimum costs.

Character of Potential Benefits: It is estimated that 50 percent of the U.S. soils would benefit from some profile modification. Removal of undesirable profile characteristics in the arable soils used for crop production would provide for use of soil and water resources to an extent never before attained and would increase efficiency of crop production. Profile modification in rangeland could greatly increase the livestock carrying capacity.

Modification of profiles to permit unlimited use of any acre of land would return manyfold the inputs, especially for production of high-value crops as well as septic tank drain fields and certain other special uses.

Projected SMY's:

1965	1977
12	20

Tillage and Residue Management

Situation: Tillage, the manipulation of soil to create some desired physical condition, is a major production cost on most of the world's available lands that are used for crop production. Tillage affects not only crop production but also the behavior of water that falls on the land, thereby affecting sediment and chemical loss from agricultural land.

When a soil is tilled, its structure is changed by altering the arrangement and distribution of particles and voids. Adverse effects of excessive tillage have been demonstrated. However, the absolute minimum amount of tillage necessary for sustained crop production is not known. While many tillage problems are common to all crops, soils, and climates, the severity of the problem varies greatly with the particular combination of crop, soil, and weather conditions. Thus the primary objective for tillage may vary from region to region in the U.S. However, regardless of the primary objectives of tillage, certain information is necessary for wise decisions on U.S. farms. Some questions that must be answered are: How much and what kind of tillage is necessary for sustained crop production, residue management, and erosion control? What are the long-term effects of reduced tillage? Is tillage essential for disposal of crop residues and for depth distribution of essential chemicals? What are the benefits of postplanting tillage operations in row crops when weeds are controlled chemically? What influence do tillage practices have on crop residues, soil and water conservation, and air and water pollution? How much energy is expended in tilling soils? Can essential tillage be accomplished with less energy and at less cost? What machinery design will provide the most efficient conversion of energy and still accomplish the desired tillage?

A tillage research program, designed to answer the pertinent questions, is needed and should be organized on a regional basis because primary tillage objectives and procedures vary with soil and climatic regions.

Objective: To develop technology for improved tillage and residue management practices on farms.

Research Approaches: Research will be designed to: (1) Develop tillage practices that enhance water infiltration and increase water storage in the soil for plant use. These studies will describe soil parameters that enhance water intake and determine the extent to which plant residues may be used to protect the soil from erosion by wind and water and from sealing over during intense rain. They will also concern procedures for efficiently breaking up the subsoil and for creating desirable pore size distribution throughout the rooting zone of plants. (2) Develop tillage practices that reduce runoff and sediment and chemical transport. This research will concern the relation between rate of water runoff and chemical and sediment

transport, and the development of tillage practices to maximize infiltration and minimize evaporation. Studies will also be conducted to determine if tillage can produce soil aggregates that are less susceptible to erosion by wind and water and if chemicals can be used to reduce losses by erosion. (3) Develop tillage procedures that reduce tillage operations and tillage costs. This research includes development of tillage machinery that is economical to operate while doing an effective job of tillage and residue management. Such equipment must be designed to conserve energy and reduce the number of tillage operations required to produce the crop. (4) Develop tillage procedures to gain maximum benefit from crop residues. (5) Evaluate the effects of tillage methods and procedures on crops and pasture yields and on farm income.

Character of Potential Benefits: This research will decrease the cost of crop production, increase crop production, and decrease sediment and chemical losses. Decreased cost of tillage resulting from fewer operations per crop is estimated to save at least $2.00 per acre on all intertilled crops in the U.S. Increased water storage through improved tillage is estimated to increase average crop yields by at least 15 percent and reduce cost of production.

Tillage practices that increase infiltration can greatly reduce the sediment load of our streams and lakes and materially reduce water and air pollution. The long-range value of such effects to man is incalculable but would amount to billions of dollars annually.

Projected SMY's:

1965	1977
25	31

Soil Structure Formation and Stability

Situation: The organic matter content of soils in the United States has steadily decreased since they first came under cultivation. Associated with these declines in organic matter are reductions in stability of soil structure, decreases in water intake, and increases in tillage required to achieve and maintain a desirable soil condition.

The declines in soil structure have resulted in increased losses of water, sediment, and chemicals from agricultural land. In addition, the cost and complexity of soil management increase with each successive decrease in soil organic matter and structural stability.

Research has shown that long-time manurial treatments will reduce the rate of decline in organic matter and soil structure associated with continuous cultivation. However, increases in fertilizer availability, concentration of animal feeding and poultry operations, high labor costs, and a variety of other factors have greatly reduced the areas treated regularly with manure. The use of tillage alone for soil structure control often results in excessive operating costs because operations must be repeated many times. In addition, excessive tillage often results in deterioration of surface structure and in subsurface compaction. Limitations in crop production due to poor internal drainage and crusting of the soil surface often result. Our inability to produce and maintain desirable soil structure amplifies other problems such as weed control and control of soil-borne insects and diseases. Maintenance of soil organic matter and associated soil structure is aided by manurial treatments and plant residue additions, but this is not entirely satisfactory since some plant residues are deleterious to subsequent crops. Supplying plant residues through crop rotation may be economically unsatifactory due to a reduction of acreage in high-value crops.

Research has shown that organic matter content has increased in soils converted from cultivation to forest or grass. Soil structure stability increased as the organic matter content increased.

The exact procedures for soil structure control will vary regionally in the United States and will depend on the crop and management objective. The search for better methods for controlling soil structure must proceed at an accelerated rate to permit efficient and sustained crop production.

Objective: To develop technology for developing, improving, and maintaining desirable soil structure.

Research Approaches: The effects of physical, chemical, and biological processes on soil structure must be understood if successful soil structure control is achieved. This suggests a research program with three distinct but interrelated phases: (a) Development of methods for and evaluation of specific pertinent parameters of soil structure induced by physical, chemical, and biological changes; (b) quantitative description of soil

structures desired and translation of laboratory-measured soil structural changes into field soil structural changes; and (c) development of ways to produce and maintain desirable field soil structure through chemical, physical, and biological manipulations compatible with soil management objectives. Effective control of soil structure requires advancement of technology in all three phases.

Parameters of soil structure affected by chemical, physical, and biological changes can best be evaluated in laboratory studies where conditions can be controlled. These studies will include measurement of the effects of biological and chemical additives on soil bonding strength. Studies will include inoculation with micro-organisms, modification of the suite of exchangeable cations on the clay, or additions of both natural and synthetic organic compounds. In addition to determining the effects of specific additives and other treatments on soil structure, these studies will determine if laboratory measurements can be used to screen potential compounds for soil structure stabilization.

Quantitative description of soil structure and translation of laboratory measurements to soil structural changes in the field is an essential second phase in this research. Presently, it is difficult to describe a desirable soil structural condition in terms that are universally understood and repeatable. It is also difficult to infer field soil structural changes based on laboratory-derived indexes of soil structure. Special studies are needed to determine, on an energy basis, the relationships between laboratory-measured soil structural units and field conditions as expressed in soil strength and tillage draft requirements. Laboratory measurements must also be designed to express surface roughness, water intake rates, pore stability, etc. Progress in this phase would permit prediction of the effects of tillage, additives, and other soil treatments with a minimum of expense.

The final phase of this research is the development of ways to produce and maintain desirable soil structure that is compatible with soil management objectives. Phases one and two will have isolated certain chemical, physical, and biological processes that affect soil structure.

The amount of a particular additive or treatment required will vary with the soil-crop-climate situation. This research must be designed to clearly indicate the effects of physical, chemical, and biological additives applied singularly and in combination. These must be integrated and combined into management systems that are feasible and compatible with soil management objectives.

Character of Potential Benefits: This research would benefit American agriculture by decreased cost of production, increased crop production, decreased loss of sediment and chemicals, more latitude in land use planning, more consistent production, more uniform results from chemical additives, and more consistent control of soilborne diseases and insects.

Almost all soils have some structure problem. Systematic and repeatable control of soil structure would decrease tillage requirements and save at least $2.00 per acre on all intertilled crops in the United States. The decreased field traffic and reduced compaction would probably increase average yields 5 percent above present levels. Maintenance of soil structure and consequent reduction of runoff would reduce sediment loss by at least 25 percent. A similar or perhaps even greater reduction in loss of chemicals could be expected.

Projected SMY's:

1965	1977
16	32

Soil Acidity and Liming

Situation: High and ever-increasing levels of crop production and large capital inputs on the Nation's farms make control of soil acidity an increasingly important economic factor and one that is a key to improving and conserving the productive capacity of soils. Farmers traditionally have underlimed acid soils, even though liming has been financed in part by ACP cost sharing. Agricultural lime consumption presently is around 30 million tons annually, about one-third of that recommended by agronomists. With greatly increasing use of nitrogen fertilizers--up from 5.45 million tons of N in 1950 to 16.1 million tons in 1966--soil acidity in humid regions is increasing both in surface and subsoils. Productivity of the best agricultural lands not only is being impaired, but increased subsoil acidity can seriously restrict the plant root zone and create a long-lasting problem difficult to remedy. Liming rates and methods for correcting the acidity and calcium deficiency associated with shallow tropical subsoils are badly needed. On the other extreme, overliming of acid soils or land leveling on western calcareous soils can make certain essential micronutrients unavailable and drastically reduce yields. A great deal of research over the years has been devoted to soil acidity and liming, but much of it does not appear applicable to present-day situations.

Objective: To study soil acidity and liming under today's farming and land restoration situations for the purpose of maintaining an optimum environment for crop growth and conserving long-term soil productivity.

Research Approaches:

A. Determine economic and other factors presently restricting adequate lime use on farms.

B. Investigate basic soil-plant-calcium-magnesium systems with the view of developing ways for better and more adequately determing the lime requirement of soils and improving soil productivity for agriculture and land restoration.

C. Reexamine soil acidity, alkalinity, and liming from the standpoint of micronutrient toxicities and deficiencies.

D. Determine optimum liming needs for major humid region and tropical soils under present systems of cropping and high fertilizer use, particularly nitrogen.

E. Develop improved practices and methods of liming that will most effectively and economically conserve long-term soil productivity and prevent or correct subsoil acidity.

F. Determine liming requirements for establishing vegetation on difficult sites such as strip-mine spoil areas and highway roadsides.

Character of Potential Benefits: Sound liming practices and adequate lime use could possibly improve the productive capacity of humid region soils by 20 percent. Should subsoil acidity restrict root growth to the plow layer, yields of deep-rooted crops could be reduced as much as 50 percent.

Projected SMY's:

1965	1977
19	29

Efficient Use of Plant Nutrients

Situation: Much of the research conducted on plant nutrient use is obsolete as a result of the continuing and rapid introduction of new technology and improved management systems on the Nation's farms. Fertilizers have become a major farm input. High fertility farming is now practiced in most of the advanced agricultural areas of the country, and the basic fertility levels of the soils, particularly phosphorus, have increased. New crop varieties with their high yield potential are more fertilizer responsive, and their requirements for individual nutrients may differ from older varieties. Cropping systems are more intensive and legumes no longer are grown as a major source of nitrogen. In response to higher per-acre use and the need for labor saving on farms, methods of fertilizer distribution and application have changed. Fertilizers are more concentrated, contain less secondary and micronutrients, and many contain chemical compounds not used a few years ago. Most of the nitrogen for direct application are now applied in gaseous or liquid forms. Deficiencies of secondary and micronutrients are becoming more widespread. Soil testing and plant tissue analysis have gained in popularity but require improvement. And a national concern is developing that heavy fertilizer applications may lead to pollution of streams, lakes, and ground waters.

Objectives: To improve the effectiveness and efficiency of plant nutrient use on farms and forest lands to insure the continued efficient production of quality food, fibers, and wood products within the framework of sound and proven conservation of soil and water resources.

Research Approaches:

A. Conduct basic investigations on fertilizer-soil reactions as these may relate to nutrient availability, movement, and to uptake by different plant species. New nitrogen- and phosphorus-containing fertilizer compounds, sulfur compounds, and practically all of the micronutrient carriers need investigation.

B. Evaluate through carefully controlled field and laboratory investigations the changing plant nutrient requirements of the Nation's farms and soils as expressed in terms of nutrient rates and ratios.

C. Evaluate interacting effects of plant nutrient applications with respect to water management, liming, land forming, minimum tillage and crop residue management, and other practices currently being used on farms.

D. Investigate plant nutrient needs and use on new crop varieties, and new or modified soil, crop, and water management systems before their release.

E. Evaluate new fertilizer materials used as sources of plant nutrients--particularly nitrogen, phosphorus, and the micronutrients--and determine the conditions under which they can be utilized most effectively.

F. Evaluate effectiveness of existing fertilizer application methods and develop new or improved methods that will result in the most efficient plant nutrient use at lowest application cost and which, at the same time, will minimize physical, chemical, and biological damage to the soil.

G. Place special emphasis on field investigations relating to the micronutrients. (This includes delineating areas and soil and crop conditions where specific micronutrient deficiencies are most likely to occur; methods of application; effectiveness of different sources; their residual carryover in soils; determination of levels at which deficiency and toxicity occur, etc.)

H. Determine the extent that nitrogen and phosphate fertilizers are contributing to lake, stream, and ground-water pollution, and develop ways to reduce pollution if it exists.

I. Improve and field calibrate soil and plant analytical methods and procedures for predicting and diagnosing plant nutrient needs.

J. Develop systems for complete monitoring (crop logging) of nutrient needs throughout the crop production cycle both to increase the efficiency of crop production and reduce possibilities for nutrient pollution.

K. Develop sets of standards for human and animal foodstuffs which would define upper and lower limits of nutrient content and form, as well as proteins and vitamins.

L. Develop improved and efficient forest fertilization practices.

Character of Potential Benefits: Over 14 million tons of primary plant nutrients (N, P_2O_5, and K_2O) are being used in the United States, costing the farmers about 2 billion dollars annually. Payoffs of efficiencies gained through research can be very large. Also, improvements in food quality, control of pollution if it exists, and conservation of soils are of concern to all citizens.

Projected SMY's:

1965	1977
53	70

Microbial Activities in Soils

Situation: The microbial population of soils is vast, easily changed, and influences profoundly the welfare of the growing plant and the reactions that occur in soils. Modern-day farming and forestry practices involving use of large amounts of fertilizers, pesticides, and crop residues undoubtedly exert tremendous influence upon microbial activities, both good and bad. However, little is known of what actually occurs under field conditions or what can be done toward better utilizing the micropopulation in improving production, soil and water conservation, and the efficiency of various farming and forestry practices.

Much needs to be investigated. Up to 50 percent of all nitrogen applied in fertilizers is irretrievably lost through volatilization and leaching. Since these losses are rooted in the microbial transformations taking place in the soil, control of microbiological activities through use of chemical inhibitors or some other means might greatly improve recovery. Use of pesticides, injections of anhydrous ammonia, and localized applications of concentrated fertilizer may be adversely affecting the micropopulation and the plant-root environment. Activities of free-nitrogen fixing organisms in the soil may be inhibited under current practices; or with adequate knowledge, practices might be devised that would encourage their effectiveness. Ways need to be found to better utilize crop residues by formation of organic compounds more effective in soil structure maintenance.

Objective: To study soil microbial relationships with the aim toward improving the plant-root environment and developing better and more efficient farming practices.

Research Approaches:

A. Reinvestigate the nitrogen cycle in soils and explore ways, including the use of chemical inhibitors, to improve nitrogen fertilizer efficiency and reduce losses.

B. Study the effects of current practices of fertilizer application, crop residue management, liming, use of pesticides, fumigants, etc., upon the microbial activity and balance in soil, particularly as they may relate to moisture relations, crop growth, organic matter decomposition, and the buildup of crop pathogens.

C. Determine if micropopulations can be manipulated in a manner that will encourage humus formation, improve the plant-root environment, control soilborne diseases, etc.

D. Determine role of soil micro-organisms in degrading pesticides in soils.

E. Make new estimates of biological nitrogen fixation and ascertain the extent to which it is affected by continued high applications of nitrogen fertilizers, and explore ways to increase both symbiotic and nonsymbiotic nitrogen fixation.

Character of Potential Benefits: In the United States, about 700 million dollars annually are spent on nitrogen fertilizers. Reducing losses by only 10 percent would save farmers 70 million dollars annually. Benefits from other parts of the study might well exceed this.

Projected SMY's:

1965	1977
18	27

Soil-Water-Plant Relationships

Situation: Water is a dominant factor in plant growth. It is involved in all metabolic processes relating to plant development. Despite its essential nature, we have only limited understanding of properties of soil water and of the nature of its effect on plant processes. There is need to relate plant growth processes to the water status of the plant and, in turn, the water status of the plant to soil-water stress under different environmental conditions. Only through understanding of such relationships can management practices for improved efficiency in the use of water by plants be developed. The potential for greater efficiency in consumptive use of water by plants is high since only a small fraction is used in photosynthesis. Information is needed on procedures for reducing transpiration and on plant changes, if any, resulting from such reduction. Procedures are needed for measuring soil moisture stress in areas immediately adjacent to plant roots. Lack of such procedures has confounded numerous experiments on plant-water relationships. Critical studies are needed on interrelationships of moisture level, soil crusting and germination, seedling emergence, and stand establishment of crop plants.

Objectives: To determine relationships of soil and plant moisture stress to plant growth processes. To relate soil physical properties to plant behavior.

Research Approaches:

A. Develop procedures for more precise measurement of soil and plant moisture stress.

B. Relate soil moisture tension to rate of plant growth and quality of plant product.

C. Relate soil and plant moisture stress to environmental conditions.

D. Seek procedures for reducing and controlling transpiration loss from plants.

E. Relate plant establishment and growth to soil physical conditions.

Character of Potential Benefits: Decreased cost of crop production and increased efficiency of water use in agriculture. Agriculture's share of diverted water is expected to decrease as other demands increase. Greater water-use efficiency would permit continued or expanded crop production with reduced water supply. A one-percent decrease in cost of crop production would amount to many millions of dollars.

Projected SMY's:	1965	1977
	30	45

MANAGEMENT OF SALINE AND SODIC SOILS

A permanent irrigation agriculture depends upon maintenance of a positive salt balance on the land under irrigation. This means, simply, that the output of salts per unit of land in drainage must exceed the input of salts from all sources.

The productivity of soils is impaired by salt accumulation in the root zone. Rainwater and irrigation water carry some salt, and salts may be added as fertilizers or amendments. These salts accumulate in soil as water is removed by evaporation or transpiration unless they are leached from the root zone by large quantities of water occurring as rain or applied by irrigation.

While impeded drainage is the major cause of limited leaching, under-irrigation and limited permeability are also important causes. It will be obvious that the quality of the input water will control the amount of leaching required to maintain a positive salt balance. The problem of salt balance is further complicated where the soil to be irrigated naturally contains large amounts of salts.

Salt-affected soils are usually described as saline, sodic, or saline-sodic. A high proportion of sodium relative to calcium and magnesium commonly induces undesirable physical conditions that impede water movement and plant growth. The reclamation of saline soils depends upon establishing adequate drainage and a leaching regime. The reclamation of sodic soils is usually more complex because physical impedances must be removed before normal water movement (leaching) can be established to drains.

The ultimate goal in the management of salt-affected soils must be to reduce the salt levels to a practical minimum. There are three aspects to this broad area of managing soils where salts are a factor; (1) management of crops in saline or sodic environments, (2) development of a rational system for salinity control, and (3) prediction of consequences of achieving salt balance to quality of water entering nonagricultural uses. The research requirements of each of these three aspects are treated separately.

Dynamics of Leaching and Salinity Control

Situation: The status of the theory and practices of salinity control may be summarized as follows: (a) The basic factors governing water and salt movement in soil are reasonably well understood; (b) only a start has been made toward integrating these factors into comprehensive models concerned with quantitative movement of salt, and (c) existing theories are not being widely applied to the prediction of dynamic changes in salt and water regimen caused by irrigation under field conditions. The diagnostic techniques for identifying salinity and sodic problems are reasonably satisfactory but these techniques are applied to small samples that represent single points in time and space. Salinity control in the field, on the other hand, involves prognosis of changes in the chemical, physical, and hydraulic properties of dynamic systems as contrasted with steady-state systems. Many aspects of management (irrigation systems and regimes) and land development (drainage installations, etc.) contribute to these changes.

Objective: To achieve more efficient use of the available land and water resources by improved quantification of the leaching process.

Research Approaches:

A. Improved formulation of leaching theory.

B. Further development and field testing of computer models for predicting changes in the composition and concentration of percolating water and the related changes in the soil.

C. Studies to derive drainage criteria for efficient control of transient ground-water levels.

Character of Potential Benefits: In the arid West, excessive concentrations of salt in the soil have impaired the productive capacity of approximately 28 percent of the 34 million acres of irrigated lands. The problem also occurs in seaboard areas where salty waters enter the soil during storms and encroach into heavily pumped aquifers.

The major benefits accruing from successful accomplishment of this research are of three kinds: (1) Increases in crop production, (2) conservation of water, and (3) improvement in the quality of water in the Nation's streams. There is a pressing need to improve efficiency of water use by irrigated agriculture. It is estimated that about one-half the applied water used for irrigation passes beyond the root zone of irrigated fields. In most cases, this is far more than the amount required to maintain soil salinity at levels favoring high production. If the amount of water required to pass the root zone to maintain favorable salinity levels could be more

precisely ascertained, then practical programs could be enacted to encourage better use and conservation of water. Improved knowledge of the leaching process would also provide guidance to State and Federal water entities concerned with the control of salinity levels in streams. In particular, a more rational basis would be available for establishing stream water quality standards and for developing enforcement regulations. In planning irrigation projects, a more efficient basis would be provided for determining water requirements and this should lead to savings in the construction and operation of the developments.

Projected SMY's:

1965	1977
11	31

Influence of Irrigation Return Flows on Receiving Waters

Situation: Sound irrigation practices require maintenance of a positive salt balance within the root zone of irrigated soils. The application of irrigation water to soil results in the redistribution of the salts. Depending upon circumstances, some of the salts may precipitate in the soil as insoluble salts, additional salts may be dissolved and brought into the soil solution, and sometimes a significant increment of the salt load may be removed in the harvested crop. The remaining excess of soluble salts must then be leached out of the root zone. Beyond this depth the dissolution of additional salts may occur. On irrigated lands this additional pickup of salts in the percolating water varies from negligible amounts to over 6 tons of salt per acre irrigated. These salts increase the salinity of receiving waters and tend to impair their suitability for irrigation, municipal and industrial, fisheries, and recreational uses. Only a small research effort is being made to evaluate the magnitude of the salt loading and the resulting influences on current and potential uses of the water. In practical water management, little control has been exercised over the salt output.

Objective: Develop methods for maintaining the quality of waters that receive return flows from irrigation.

Research Approaches:

A. Conduct field-scale studies to measure the influence of irrigation on the salt load of receiving waters, both surface and ground water.

B. Develop water management and cropping systems which induce solution, removal, or precipitation of salts.

C. Develop chemical and biological methods for removing or reducing the concentration of undesirable ions.

D. Develop systems analyses procedures for predicting the influences of irrigation water management on the quality of receiving waters.

E. Conduct watershed studies to evaluate the comparative contributions of irrigated land, nonirrigated land, and urban areas to the mineral salt loading of receiving waters.

F. Develop economic models to measure impact of water quality on agricultural, industrial, recreational, and other uses of water.

Character of Potential Benefits: Conservation and improvement of the quality of our water resources is an important national objective. Programs of salinity control are now underway by private, Federal, and State entities.

Such programs should be founded upon sound scientific principles and applicable economic measurements of the detriments caused by increasing the salinity of our streams.

In agriculture, economic losses are incurred by salinity increases through reduction in crop yields caused by higher salinity levels in the soil solution, use of excess water for leaching, a reduction in acres irrigated, shifts in cropping patterns to salt-tolerant crops (which usually provide lower net returns), or combinations of these factors. These losses further cause net economic losses in the related agricultural processing industries. Increased mineralization of municipal water supplies results in increased treatment costs, or alternately, in the use of more soap or detergents. Industrial losses occur usually through greater costs associated with using mineralized water as boiler feed water. As water becomes more saline, suitability for recreational use is also impaired. The conditions in the Salton Sea currently highlight such an effect. The results from the physical and economic research outlined would form a necessary foundation for the development and installation of sound salinity improvement programs.

Projected SMY's:

1965	1977
12	32

Management of Saline Environments for Crops

Situation: Considerable research has been accomplished on plant-water-soil interactions as related to salinity and sodic conditions. Using this body of knowledge, it is often possible to obtain fair yields on salt-affected soils. Restrictions nevertheless are imposed on the crop yields attainable or on the cropping pattern, thereby limiting the irrigators' net farm increase. Additional quantitative data on the tolerance of crops to salinity under a wider range of climatic conditions are needed. Improved understanding of the ranges in salt concentration and distribution of salt within the root zone as related to crop tolerances at various stages of growth should be developed. The physiology of salt tolerance is not well understood and advances in such knowledge are essential to development of management systems and in breeding salt-tolerant varieties. Very little work has been done by geneticists and plant breeders to develop salt-tolerant varieties because the mechanisms of tolerance are not well understood.

Techniques for the management and reclamation of sodic soils, especially of solonetz, are not well developed. Solonetz soils have been excluded from many irrigation projects but pressures for new lands may well lead to their inclusion in the future. Special methods are needed to cope with the difficult physical conditions imposed by excess sodium or textural characteristics of solonetz profiles.

Objectives:

A. To provide an improved quantitative basis for measuring economic influence of salinity levels and to improve crop production with saline water or soils.

B. To develop improved methods for managing crops on saline or sodic soils.

Research Approaches:

A. Field studies to determine the tolerance of crops to salinity under various climatic conditions.

B. Determination of the influence of various water management methods on salt movement and distribution in the soil and the integrated effect of such movement and distribution on crop yields.

C. Development of salt-resistant crop varieties through plant breeding.

D. Development of management criteria for use of brackish water of various qualities under a wide range of soil, crop, and environmental conditions.

E. Studies of soil profile modification practices, tillage methods, use of soil amendments, and cropping practices adapted to conditions on saline and sodic soils.

F. Investigations of the interactions of dissolved and adsorbed ions, microbial activity, organic matter, as related to interactions with soil structure and the movement of moisture in the root zone of salt-affected soils.

G. Development of new techniques and equipment for measuring the salinity, sodic, and related chemical status of soils and irrigation waters.

Character of Potential Benefits: The State and Federal research and action agencies concerned with water resources development have responsibilities to assist farmers by increasing living standards along with concomitant responsibilities to the public to lessen the degradation of water supplies. The continued prosperity of the Western States is largely dependent upon irrigated land. As water supplies are more fully utilized, the salt loading of streams is expected to increase. Sound plans for sequential use of water and long-range plans for reducing mineral pollution of streams are needed. In arid regions, sequential use of water for irrigation causes a progressive increase in the salinity of the river. The users at the lower end of the stream must therefore adapt to using more highly saline water by applying an excess to meet leaching requirements or selecting crop patterns that can tolerate the increased mineralization. Development of management systems and crop varieties that tend to optimize yields with saline water and soils holds promise of increasing production on about one-fourth of the irrigated land in the West. Moreover, the establishment of public programs for salinity control will need to be based on measurements of the benefits and costs of installing salinity control and improvement works. It is thus essential that a sound body of scientific facts be available to appraise the yield decrements caused by increased salinity in the irrigation water supply. The research, as described, is aimed at (1) optimizing use of saline water, (2) providing a broader range of alternatives in the development of long-range programs for sequential use of water, and (3) providing economic measurements essential to the installation of salinity control and alleviation programs.

Projected SMY's:

1965	1977
7	22

ALTERNATIVE USES OF LAND

Our national supply of land is fixed, in a physical or spatial sense, but it varies in quality. This variation in land quality has an important bearing on national land policy and planning decisions. The effect of productivity increases, made possible by research and technology change, has been to expand our agricultural production capability; thus the total supply of land available for agricultural production is abundant. A crucial issue is--how extravagantly, and for what other purposes, should prime agricultural lands be used? Urban, industrial, recreation, transportation, and other non-agricultural land needs have increased sharply in recent years, resulting at times in extensive local conversion of agricultural land to other uses.

Adjustments in land use occur almost continuously. These adjustments have become more complex due to rapidly changing demands and increasing competition for land. In some instances, retention of land in agriculture or forestry may be necessary to assure economic growth, preserve prosperous communities, and to enhance the environment. In other instances, ownership or other institutional impediments may interfere with the allocation of land to other uses. Land use planning is often recognized as a needed measure, but planning is weakened at times by the difficulty of being comprehensive and related to meaningful areas while at the same time being sufficiently specific to allow implementation. Wise decisions and effective planning, at all levels of government, depend upon more adequate knowledge of the relationships between land resources and economic development. Information is needed on types of land use and their rates of change, on the way in which ownership factors influence uses and changes in use, and on the alternative means for achieving land development and conservation objectives of local and regional plans.

The following four statements set forth more specifically what should be achieved in analyzing land uses and in planning future land uses. The four statements are directed in turn to the following areas of work: (1) Inventory and analyses of land utilization, conservation, and development; (2) land resource institutions and tenure; (3) improved methods of planning land resource use and development; and (4) impact of population growth, technology, and alternative government programs on land use.

Inventory, Conservation, and Development of Land Resources

Situation: Population growth, advances in agricultural production technology, changing consumer demands, increased urban concentration, and other factors cause changing demands for the Nation's supply of land. Public programs are required to aid in land-use adjustments, conservation, and development of land resources commensurate with the growing needs of a more affluent society. As a basis for improved policies and effective programs, systematic research should include analyses of current levels and trends in major uses of land, economics of land development and conservation measures, and economics of alternative land uses.

Objectives: To provide an inventory and continuing record of land supplies, uses, and land improvements; to determine the adequacy of the land resource base for projected national agricultural output requirements and nonagricultural land needs; to appraise and analyze national and regional needs for land conservation and economic development; and to develop and utilize methods for acquiring and manipulating data on uses and potential of land resources, including use of data processing methods, storage, retrieval, and analysis of data.

Research Approaches:

A. Maintain national, State, and regional inventories of major uses of land and land improvements.

B. Analyze the relationships among land resource characteristics and economic development, including (1) the role of alternative land uses in local and regional economics in view of the natural features of the landscape, and (2) the effect of economic development on land use patterns and intensities in immediate and adjacent areas.

C. Identify the location and availability of land for future agricultural use and determine its relative productivity.

D. Analyze aggregate land requirements for various purposes in consideration of (1) industrial, residential, recreational, forestry, agricultural, and other nonagricultural requirements, and (2) alternative regional strategies to provide various levels of food and fiber, to provide alternative environmental attributes, and to provide for alternative geographic distribution of population.

E. Study the extent and effect of irreversible land use changes on agriculture, including (1) the effect of present and expected urban, residential, industrial, and transportation uses on the agricultural land base; (2) the extent and significance of reservoir inundation and

other flood plain management techniques; and (3) lands acquired by public agencies for relatively extensive uses, such as recreation, wildlife, and wilderness areas.

F. Photogrammetric techniques employed include the use of airphoto comparison analysis and remote sensing as a means of improving land use and management research.

Character of Potential Benefits: Attainment of these research objectives will assist in the development of sound policies and effective programs for the assurance of future food supplies, for meeting future nonagricultural uses of rural resources; and for balanced economic development. Economic intelligence from this research will be required for decision making with respect to conservation, management, and development of land and related resources.

Projected SMY's:

1965	1977
11	40

Land Resource Institutions and Tenure

Situation: Attainment of goods and services from land resources is conditioned by laws, administrative measures, and related institutional arrangements that prescribe the rules and procedures for transfer, use and management of resources. Research is needed on the structure, scope and use of these legal and institutional arrangements as a means of implementing public programs designed to meet the future requirements of goods and services desired from land and related resources. Expanding population and increasing affluence are exerting pressures on the land resource for more consumptive services, including improved quality of environment, recreation, and living space. These additional demands on the land base create problems in government requiring further research in institutions and tenure.

Objectives: To analyze the effect of existing and alternative legal and other institutional arrangements on the efficient use, transfer, and management of lands and on the benefits and costs to landowners, users, communities and the public.

Research Approaches: An interdisciplinary effort is required involving participation or assistance of economists, lawyers, statisticians, systems analysts, and planners. Emphasis is on analysis of laws, administrative procedures, and legal instruments, to determine how they may be modified to achieve certain objectives. Special recognition is given to the differential impacts of alternative institutional arrangements among resource owners and communities.

A. Inventory of public and private rights in land and private, quasi-governmental, and governmental devices for controlling land use.

B. Studies of landownership and control, including private access to public lands; public access to private lands; leasing and contract arrangements; estates and inheritance; and public automated land title and record systems.

C. Studies of land use regulations and planning including zoning, easements, and covenants to determine their effect on the supply of land in given uses, land values and land use changes. Study the exercise of eminent domain, police powers, and taxation for environmental management; and study the legal incentives and restrictions in comprehensive land use planning and development.

D. Studies of resource organizations including special resource districts, such as conservation and conservancy districts; various private resource management organizations, such as condominia, syndicates, and cooperatives; uses and limitations of Federal interstate compacts on economic

effects in land and water use management; and systems analyses of institutional processes to determine success elements in land use planning and management.

E. Impacts of public investments in natural resource development on land values, community welfare, and economic growth and the economic effects of transfer payments and cost-sharing devices on resource owners and communities.

Character of Potential Benefits: Research on the ownership and control of land provides information essential to individual and group planning of land development, conservation, and use. The several research approaches outlined above seek to provide improved information on the way our land resources are owned or controlled and the associated effect on land use and income distribution. These studies will also be useful in revising legal and other institutional arrangements to increase their effectiveness toward accomplishing established goals.

Projected SMY's:

1965	1977
11	29

Improved Methods of Planning Land Resource Use and Development

Situation: Expanding population, higher levels of education, rapid strides in production technology and increases in real income produce constantly rising demand for goods and services and consequent pressure on land resources. Achievement of these demands involves public programs such as those for urban and rural development, transportation, housing, outdoor recreation, and improved environmental quality. It has become evident that comprehensive national, regional, and local planning is required to effectively serve the multitude of interests and purposes associated with land resource use. Through research, methods should be developed for reconciling these interests and purposes with larger social objectives via the planning process.

Objectives: To improve the resource planning process through the integration and interpretation of physical, social, and economic research; to develop guidelines for use in resource planning and for making conservation and development investments in resources; and to assist in formulating new research for improved resource management and development.

Research Approaches:

A. Appraisal of alternative institutional means of attaining coordinated planning among those jurisdictions and agencies engaged in natural resource planning--in regional and local planning.

B. Appraisal of resource developmental objectives with regard to alternative means of attainment and with regard to their economic and social significance.

C. Economic analysis of multiple use and sequential use of resources.

D. Cost sharing for land resource investments and means of implementation.

E. Analyses of secondary effects of resource development with règard to economic development, including changes in employment, income and natural resource use.

F. Evaluation of effects of installed development projects.

Character of Potential Benefits: Pursuit of these research approaches will provide information for improving methods of land resource planning; knowledge obtained through these studies will be useful in analyzing alternative means of meeting resource planning goals and for evaluating the social and economic significance of alternative goals, themselves. *Ex post* study of land conservation and development programs will provide useful data for continued improvement of public programs.

<u>Projected Scientific Man-Years</u>:

1965	1977
0	12

Impact of Population Growth, Technology, and Alternative Government Programs on Land Use

Situation: The burgeoning need and desires of people for new and different uses of land have strained the capabilities and ingenuity of land resource managers to the utmost. Inasmuch as the Nation's supply of land is fixed, the additional demands on it have caused conflicts and, in places, a deterioration of land quality. As many decisions on land use alterations are irreversible, the decision-making process becomes highly important.

Although the three causes of impacts mentioned in the title are interrelated, each has certain impacts with which it is primarily concerned. For example, population growth directly affects the amount of land needed for housing. New housing is principally located in suburban areas, some of which have been productive agricultural land. Population growth has also created the need for more recreation areas, roads, and waste disposal areas. New technology has created spatial demands for surface mining, airports, and highway systems, power and irrigation dams, and many others. Federal government programs, such as the military, reclamation, national forest system, national park system, and wilderness program encompass huge land areas. In addition, State and municipal governments have increased demands for land, particularly in the area of outdoor recreation and open space.

Most of these uses of land are single-purpose uses, and many are essentially irreversible after designation. Airports, highways, parks, and wilderness areas fall in this category. Surface mining is an apparent destruction of the land surface, but rehabilitation techniques are being devised. However, there is growing effort to provide more than one use on the same area of land. The military and space agencies have been looking toward timber growing or agricultural uses for the large areas in their jurisdictions. Wildlife and water supply are other products of these areas. Multiple-resource management principles have been applied by the Bureau of Land Management, the Forest Service, State agencies in charge of managing wildlands, and forest industries. The multiple use of an area may be considered an alternative to any one of the single uses applied to a land area. A form of multiple-resource management is sequential use management, where one activity follows another as surface mining usually follows timber management, to be in turn followed by some other use, such as recreation.

Effective multiresource management in the past has been largely an accidental happening. In many instances, the consideration given to one or more of the land uses has been inadequate and the results have been troublesome. Guides are needed to determine the best combination of uses or systems of managing lands for crops, timber, forage, water, recreation,

wildlife, and other purposes. Furthermore, the impacts of multiple-purpose activities on land quality and stability are more complex and even less well known than in single-purpose management.

Objectives: To develop techniques for resolving conflicting demands for land use; to develop a decision-making process for selecting sizes of areas and combination of uses for wildlands and other open-space areas; and to determine the impact of conflicting and complementary land uses on the well-being of the land.

Research Approaches: The effort needed here will be interdisciplinary, requiring sociologists, recreation specialists, ecologists, biologists, hydrologists, soil scientists, foresters, economists, and systems analysts. Specific items to be studied are:

A. Studies in the social sciences

1. Needs of people demanding alteration of land use. What are the needs of people requiring housing space, recreation space, etc., at the expense of agricultural or forest land? There must be an optimum-size area for an individual, family, or community in each land use. The size of parks, wilderness areas, and military bases are often sources of contention.

2. Identification and improved measurement associated with alternative land uses.

3. Analysis of on-site and off-site social and environmental benefits of open-space land uses. For instance, this might include evaluation of weather, air purity, and noise abatement effects stemming from parks and buffer areas in terms of land values and aesthetic improvement.

B. Biological studies

1. Effect of alternative and multiple land uses on wildlife.

2. Effect of wildlife on the environment. Wildlife creates interest in the urban or suburban community, provides hunting and fishing experiences. Adversely, over-populations of wildlife can damage farm and forest crops.

3. Effect of alternative and multiple land uses on vegetation.

C. Soil studies

1. Effect of alternative and multiple land uses on soil in terms of compaction, structure, infiltration and percolation rates, erodibility, and fertility.

2. Techniques to maintain, improve, or rehabilitate soil quality resulting from various land uses.

D. By systems analysis, determine guides to combine land uses efficiently.

Character of Potential Benefits: Productive research on the impacts of people, technology, and government programs on land use will provide much needed information, improved land quality and stability, and a host of intangible benefits. If a fraction of the lost time, effort, and funds resulting from controversy and wrangling between pressure groups can be saved, the benefits will be great. The value to the environment will be very important.

Projected Scientific Man-Years:

1965	1977
0	36

POLLUTION

Our ancestors settled in a relatively unspoiled land, easily capable of absorbing the wastes of its industries, animals, and human population. As a result of our abundant natural resources, the human inhabitants have increased greatly. They have formed gigantic population concentrations in and around major cities and industrial areas, have become dependent on the repeated application of synthetic chemicals for pest control in urban areas and in agriculture, and have concentrated the increasing numbers of livestock near heavily populated areas. All of these activities have led to air, soil, and water pollution.

Various individuals and groups have claimed that soil and water pollution have resulted from repeated applications of insecticides, fungicides, herbicides, and fertilizers. On some specialized crops, micronutrients have been applied in large enough quantities to inhibit the growth of some plants. In some instances, fertilizer has been applied, either as animal wastes or in the inorganic form, in sufficient quantities to be suspected as a source of nutrients in surface and ground waters.

Even though the things mentioned above are frequently cited as pollution sources, little or no quantitative information is available. There are indications that the soil has a tremendous capacity to decompose compounds that pollute crops and ground and surface waters. However, the soil's capability to accomplish this for extended periods is not known, nor are the mechanisms involved understood. Of immediate concern is the question of how much animal waste can be used on the land for crop production without polluting surface or ground waters or decreasing the value of the crop growing on the land.

The problems described above require a multidisciplinary approach. This will require involving other fields, such as limnology, fish and wildlife management, and air pollution which can be supplied by departments and agencies outside of agricultural areas.

Plant Nutrients and Fertilizers in Pollution

Situation: Population growth and the continuing demand by consumers for food at lower cost have resulted in drastic changes in agricultural production. Along with lower labor inputs, higher machinery investments, and greater land area per farm, there is a substantial increase in the use of chemical fertilizers. It is now estimated that fertilizer salts account for one-third of the food output of the United States. Accompanying this boon to production is the possible detrimental effect these fertilizer salts have in causing pollution of surface and ground waters.

Interest in pollution abatement has grown concomitantly with a rapid expansion in farm use of fertilizer in recent years. In addition to farmland use, application on lawns, golf courses, parklands, highway rights-of-way, and other areas is growing rapidly. The trend to even higher levels of use will continue and may approach rates of usage in densely populated areas such as the Netherlands, which in 1965 used more than 10 times as much nitrogen per acre of cropland as the United States. Use of fertilizer on forest lands will continue to increase. Decomposition of residues from crops and forestry operations constitute a further variable and considerable contribution of nutrients to various ecosystems. Undoubtedly some of the nutrients applied enter surface and ground waters and contribute to eutrophication and other effects of pollution. However, only very rough estimates are available for most sections of the country as to the relative contribution of fertilizer use, other agricultural operations, forestry operations, livestock on farms and in feedlots, and sedimentation to the entire pollution pictures. Little is known about the potential contribution of plant nutrients from agricultural operations at present and at projected rates of fertilizer application, and about the possibilities of reducing and minimizing that contribution. Variations in timing, placement, and kinds of materials used may offer opportunities for great improvement.

The mechanisms of movement of extremely soluble materials such as simple nitrate are not fully understood and need to be studied in various soil and environmental situations. Highly adsorbed nutrients, such as phosphate, may be moved almost exclusively by physical transport of the particles of the soil on which they are sorbed, but means need to be developed for minimizing or reducing to zero any movement whatever into watercourses and bodies. Innovations in products and product treatment can contribute greatly to technology capable of pollution reduction. Newer slow-release nitrogenous materials are examples of the possibilities.

Objectives:

A. To establish, for major soil and agricultural areas, nutrient leaching rates under cropping systems and forestry management situations likely

to prevail. Quantitative data are needed to establish benchmarks and define the relative contribution of fertilizer.

B. To describe the cycling of nutrients in phases of ecosystems including the contributions of forest and crop residues, and determine minimal and optimum levels of nutrients in water for major kinds of aquatic plant life.

C. To develop means of minimizing the contribution of agricultural operations, forestry and wood-using operations to pollution of water resources, and reducing the damage where nutrient levels in water bodies are already high.

D. To determine the "natural" level of plant nutrients in runoff from noncultivated land.

Research Approaches:

Objective A can be approached by well chosen and well executed studies of distribution of pollutants in soils, ground waters and runoff waters, similar to that done in the Middle South Platte Valley in Colorado in 1966 and 1967.

Objective B will be gained by careful studies of organic matter levels and microbiological activity in soils and waters associated. Growth of algae and other organisms in water bodies under controlled environment and nutrient supply conditions will be used to determine minimal and optimum conditions for growth. A nutrient loss prediction equation should be achieved which will utilize the benchmark information sought under objective A and extend the scope of knowledge by prediction to areas not actually measured.

The harmful effects of pollutants deriving from nutrients entering ground and surface waters may be susceptible to amelioration by precipitating or coagululating an essential nutrient ion to a level in the solution phase below the critical or minimal of the organism causing undesirable effects in that water body. Possibilities here include the spreading of finely divided iron ore and taconite wastes or spent pickling acid from steel mills to precipitate phosphorus, for example.

Development of slow-release fertilizers or of fertilizer application regimes which minimize escape from the land must accompany other aspects.

Character of Potential Benefits: It is possible for man to produce his food needs at an acceptable cost without destroying aesthetic aspects of his environment such as lakes and watercourses, or greatly reducing the utility of surface and ground waters for recreation, domestic and industrial uses. Research of the nature described can be the basis for developing

programs and materials needed in crop production which will make possible the above goals. This is of ultimate value to all mankind, and is increasingly important as available land and water per capita decrease.

Projected SMY's:

1965	1977
12	47

Agricultural Pesticides and the Pollution of Soil and Water

Situation: In 1964, 229 million pounds of DDT and the aldrin-toxaphene group of insecticides, 108 million pounds of 2,4-D, 35 million pounds of sodium chlorate, 24 million pounds of 2,4,5-T and 79 million pounds of two major fungicides were produced for agricultural use. The average rate of insecticide application in several recent years has exceeded 2 pounds per harvested acre for all U.S. cropland. When one considers that in the herbicide group alone there are about 100 major chemicals, the potential impact of all pesticides on soil and water contamination is considerable. It is known that among major chemicals, there is a great difference in persistence when applied to the land, and this difference is further complicated by soil variables. Chemical selection, regimes of use, cropping systems to minimize harmful effects, and other aspects must be integrated into programs of effective action. Because of the complexity of the systems (plants-soils-environment), it is essential that soil scientists be a part of research programs set up to investigate these problems.

Increasing pressure for efficiency in agriculture has resulted in consistent increases in use of insecticides, nematocides, herbicides, and fungicides. With rising population and increased demand for lower cost food, this pressure will increase, and pesticide usage is not likely to decrease. The dissipation and decomposition mechanisms, intermediate degradation products, detoxification mechanisms, and biocycling of many of these pesticides are essentially unknown.

Objectives:

A. To quantify the contribution of agricultural pesticides to pollution of man's environment, including the long-time effects on major aquifers and the movement in irrigation return flows.

B. To establish the most realistic possible levels of tolerance of contaminants for man, livestock, fish and wildlife, in land, plants, and water.

C. To determine the reactions that pesticides undergo in soils as related to their persistence and fate.

D. To develop programs and devise economical systems capable of eliminating or minimizing pollution from agriculture.

Research Approaches:

A. Select typical watersheds and soils in the major agricultural and forest areas of the United States; collect soils, runoff and water escaping below the root zone and estimate the movement of pesticides into surface

and ground waters. Existing erosion and runoff sites can be utilized for many of these studies. Establish uncontaminated or present levels; determine rate of change of pesticide levels in soils and waters.

In order to be most significant, research on pesticides in an environment (e.g., soil root zone of a plant) must be done under the scrutiny or surveillance of knowledgeable scientists.

As knowledge of the metabolism of pesticides and the intermediate degradation compounds improves, measurement techniques should be updated to encompass the known array of derivatives. As knowledge of the significance of pesticides and derivative residues increases, the scope of measurements can be appropriately modified.

B. Refine and update analytical methods, so that the required precision of measurement of new and old pesticides can be attained.

C. Continue and increase the efforts to establish tolerance levels of man, domestic animals, fish and wildlife, and various organisms in the food chain.

D. Evaluate the role of mineralogical, organic, and biological constituents of soils as agents and factors in complexing, detoxifying and metabolizing pesticides. Various soil additives may be capable of greatly enhancing pollution-reducing capabilities of soils.

E. Integrate results of approaches A-D into programs of recommended action through appropriate agencies.

F. Analyze potential legal, organizational, and cost-sharing problems encountered in interpreting action programs, and their effects on farm income and costs of producing food and fiber.

Character of Potential Benefits: The benefits of such a program of research and implementation of the results obtained can be simply stated:

A. A continued abundant supply of uncontaminated food and fiber.

B. Minimal pollution of water and soil consistent with tolerances.

Projected SMY's:

1965	1977
35	70

Sediment as Related to Land Use and the Quality of Environment

Situation: The erosion of land surfaces and sediment produced thereby is a multiedged sword in the deterioration of our environment.

A. It reduces the productive power of the land and increases the production cost to the farmer and real cost to society in terms of resource depletion because of the increased pace of usage of mineral fertilizer deposits. Thereby, it hastens the time when real cost of food and fiber will go up.

B. It reduces the esthetic quality of the environment in terms of lower quality of streams and lakes, lifespan of reservoirs and lakes, reduction in fish and wildlife habitat, and capacity of flood-prevention reservoirs.

C. It increases the cost of water-treatment maintenance of waterways, harbors and control structures, and maintenance of highways and bridges.

The consequences of runoff from cultivated grazing and forested lands, mining operations and construction sites become increasingly serious as populations increase and as a culture or subculture undergoes transition from grazing to cereal grains to row crops. Frequency and intensity of tillage and exposure of land surface to eroding forces increase as the above transition progresses. Furthermore, forces which under natural vegetation operated to engender and stabilize soil structure and minimize erosion often are quickly reduced to near insignificance under modern agriculture. Over 500 soil analyses from 17 Western States and 4 Canadian Provinces showed marked correlation of soil structure stability (resistance to erosion) with organic matter content. Row crop culture destroys organic matter more rapidly than less intensively cultivated crops.

Sediment production in continental United States is variously estimated at around 4 billion tons per year. About 500 million tons reach the mouth of the Mississippi River. It is estimated that four times that amount per year is moved off agricultural lands but comes to rest somewhere before the Delta is reached. About one-fourth of the sediment in watercourses comes from poorly managed forest and rangelands and from nonagricultural lands. Large volumes of sediment come from bank-caving along the lower reaches of streams. Surface or strip-mining operations frequently leave large areas exposed and nonvegetated for long periods of time. Construction sites for residences, businesses, highways, and other purposes are often major contributors to the problem.

Objectives:

A. To identify and estimate the contribution to sediment production of the major phases of land use, including, at least; agriculture, urban and highway construction, mining, and forestry, residential construction.

B. To define and evaluate as clearly as possible the factors, physical and economic, for the major soil regions of the U.S., which have potential to reduce runoff and sediment production from agricultural, grazing and forest lands, and to investigate economic incentives and physical and chemical practices which can be utilized to reduce sediment production.

C. To evaluate the contribution of silt and clay in watercourses, lakes, and reservoirs to nutrition of algae and other plants, and other polluting factors in our lakes and reservoirs.

D. To formulate and recommend to appropriate action agencies programs to minimize sedimentation damages and eutrophication processes.

Research Approaches: More accurate and lower cost estimation procedures for sediment production and identification of sources of sediment will be needed, depending on the detail of information required. Remote sensing techniques may prove to be useful tools. Certainly more watersheds than are presently being monitored will have to be instrumented for a more precise knowledge of the problem. Type of agriculture, topography, tillage practices, and various inherent soil characteristics will be evaluated and related to sedimentation coming from land uses mentioned in Objective A. Organic content and cycles, iron and aluminum oxide, silica, calcium, and magnesium will be among these characteristics. Resourceful and imaginative approaches with chemical and physical additives, cropping practices, tillage manipulations and possibly other means will be used to gain Objective B.

Objective C will be approached by evaluating plant nutrient sorption phenomena with silt and clay in waters of various qualities, thus identifying the instantaneous and sustained contribution of sediments to the nutrition of algae. Other indirect effects of sediment such as the temperature and light at various depths in water bodies as influenced by sediment load will be evaluated.

Objective D will require seminars and conferences between research and action and educational agencies for the formulation of workable programs to gain the desired goals.

Character of Potential Benefits: Clear, clean streams; lakes free from silt and clay; retarded eutrophication rates and much prolonged usefulness of reservoirs will be the result of effective research and utilization of the results of the above studies. Citizens of America are becoming more

and more aware of the quality of the environment as regards water, land areas for recreation, and air. Science has helped man into a position in which his food costs are a smaller fraction of his income than ever before in history; it must now enable him to do this for the foreseeable future without destroying either the productive or aesthetic aspects of his environment.

Projected SMY's:

1965	1977
12	37

Animal Wastes and the Pollution of Soil and Water

Situation: Wastes from livestock and poultry production are estimated to be 1.7 billion tons annually. Because the biochemical oxygen demand for treating this amount of domestic farm wastes is equivalent to treating about twenty times the accumulation from the population of the United States, other disposal methods must be investigated.

We have always used the land for organic waste disposal in such processes as turning under crop residue, spreading manure, or making compost. However, present-day labor and equipment prices make the costs of hauling manure to the field in excess of those for supplying the nutrients as commercial fertilizer.

Modern methods of handling livestock have resulted in most cattle being fed in feedlots ranging in capacities of 25,000 to 100,000 head. This means that large amounts of manure are produced in localized areas.

Current public concern about pollution abatement places a great urgency on obtaining knowledge of the disposal of animal wastes. If the livestock production industry is to remain profitable, disposal costs must be kept to a minimum.

Objectives: To determine the influence of soil type, slope, and total water balance on the maximum quantities of animal waste that can be applied to the land without impairing crop production or polluting surface and ground waters and to determine the effect of feedlot management on surface and ground-water quality.

Research Approaches:

A. Conduct greenhouse and laboratory studies on the plant utilization of the macro- and micro-nutrients from soil with and without added manures.

B. Devise methods for detecting those soils and crops that give the greatest response to manure applications.

C. Determine if plants respond similarly to nutrients in manures and nutrients applied as commercial fertilizers.

D. Establish the maximum quantity of animal wastes that can be applied to different kinds of soil without impairing crop quality or polluting surface and ground waters.

E. Determine the effect of animal wastes on the chemical, physical, and microbiological properties of soil.

F. Evaluate animal health as influenced by high rates of chicken litter applied to forage crops.

G. Determine the amount of nitrogen and phosphorus in the air above feedlots and in the water running off and percolating through feedlots as influenced by soil type and slope, water balance, and feedlot management.

H. Determine if subsoil aeration in feedyards can be managed to accomplish complete denitrification of percolating nitrogen compounds.

I. Determine the magnitude of ammonia loss and its significance to water via air pollution.

Character of Potential Benefits: Experts have estimated that composting or incinerating animal wastes would cost annually 10 dollars per dairy and beef animal, 80 cents per hog, and 50 cents per chicken. The development of land management for disposal of these wastes should reduce these costs to one-tenth of the incineration costs.

Projected SMY's:

1965	1977
35	140

SCIENTIFIC MANPOWER AND FACILITY REQUIREMENT

This report outlines the need for additional scientists on or before 1977. The increased manpower will be required to undertake the research described in this report. The committee assumes that the scientists will work together with students of allied disciplines. These scientists must be prepared to work together.

The projected manpower by the Task Force is less than that projected by the Long Range Study in the first three subject matter areas (Tablé 2). However, the projection for ALTERNATIVE USES OF LAND is higher than that recommended by the Long Range Study. Projected figures for POLLUTION cannot be compared with the pollution project in the Long Range Study because those include air and water.

Table 1. Current and recommended research effort in scientific man-years.

Problem area	Year 1965	Year 1977	Increase requested
APPRAISAL OF SOIL RESOURCES			
Inventory of Fundamental Properties and Processes of Soils	25	50	25
Development and Use of Soil Surveys	25	35	10
Soil Classification and Correlation	90	100	10
Soil Factors Influencing Animal and Human Nutrition	19	39	20
SOIL STRUCTURE; and SOIL, WATER, PLANT, NUTRIENT RELATIONSHIPS			
Soil Profile Modification	12	20	8
Tillage and Residue Management	25	31	6
Soil Structure Formation and Stability	16	32	16
Soil Acidity and Liming	19	29	10
Efficient Use of Plant Nutrients	53	70	17
Microbial Activities in Soils	18	27	9
Soil-Water-Plant Relationships	30	45	15
MANAGEMENT OF SALINE AND SODIC SOILS			
Dynamics of Leaching and Salinity Control	11	31	20
Influence of Irrigation Return Flows on Receiving Waters	12	32	20
Management of Saline Environments for Crops	7	22	15
ALTERNATIVE USES OF LAND			
Inventory, Conservation, and Development of Land Resources	11	40	29
Land Resource Institutions and Tenure	11	29	18
Improved Methods of Planning Land Resource Use and Development	0	12	12
Impact of Population Growth, Technology, and Alternative Government Programs on Land Use	0	36	36
POLLUTION			
Plant Nutrients and Fertilizers in Pollution	12	47	35
Agricultural Pesticides and the Pollution of Soil and Water	35	70	35

Sediment as Related to Land Use and the Quality of Environment	12	37	25
Animal Wastes and the Pollution of Soil and Water	35	140	105
Totals	478	974	496

Table 2. Current and recommended research effort by Joint Task Force and the Long Range Study.

Problem Area	1965	1977 1/	1977 2/
APPRAISAL OF SOIL RESOURCES	159	224	250
SOIL STRUCTURE; and SOIL, WATER, PLANT, NUTRIENT RELATIONSHIPS	173	254	300
MANAGEMENT OF SALINE AND SODIC SOILS	30	85	70
ALTERNATIVE USES OF LAND	22	117	40
POLLUTION	94	294	- 3/
Totals	478	974	660

1/ As recommended by Joint Task Force.

2/ As recommended by Long Range Study

3/ Long Range Study did not include projections for pollution.

National Association of State Universities
and Land Grant Colleges